

“You just have to take a bit of a risk sometimes”: Breaking the ‘Cycle of Tradition’ in Primary Mathematics

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The purpose of this study was to explore the mathematics teaching practices of graduates of a pre-service primary/early childhood education program designed to develop teachers' capacities to implement non-traditional mathematics curricula. As a complementary component of a large survey study of graduate teachers, graduates were interviewed to examine their mathematics teaching practices and influences upon their practices. The teachers indicated they were implementing personally developed, constructivist-oriented curricula, while also acting as curriculum leaders. They also spoke of how aspects of their pre-service education had provided them with the knowledge, skills and confidence to enact their beliefs about effective mathematics teaching.

A problem facing pre-service mathematics teacher education is the challenge of preparing teachers to ‘break the cycle of tradition’ of mathematics teaching and learning practices that centre on memorisation of facts, and the practice of pre-set meaningless procedures that promote a view of mathematics as lacking creativity, imagination, or critical thought. Research over recent decades indicates that “teachers continue to teach much like their forbears did” (Hiebert, 2003, p. 11), with an emphasis on teaching procedures rather than conceptual understandings. An alternative, non-traditional perspective for mathematics, often referred to as ‘constructivist’, is one in which classrooms are envisioned as places rich in discourse about important mathematical ideas, the development of mathematical meanings and understandings, and exploration of problems grounded in meaningful contexts (Clements & Battista, 1990; Sparrow & Frid, 2002).

Curriculum renewal and change efforts in recent decades in mathematics in Australia and elsewhere (e.g., Australian Education Council, 1994; National Council of Teachers of Mathematics (NCTM), 2000) set ambitious goals for schools, teachers and students by entailing a re-conceptualisation of the nature of mathematics and effective mathematics teaching and learning (Hiebert, 2003; Sparrow & Frid, 2002). To move forward in mathematics education therefore requires substantial learning by teachers and pre-service teachers with regard to their mathematics content knowledge, and their capacities and confidence to plan for and implement ‘non-traditional’ mathematics teaching practices. Thus, there is a continuing need for research into how to support teachers to develop as professionals who have capacities to break the cycle of tradition.

Within Australia and elsewhere a substantial body of research has focused on teachers' beliefs and attitudes, related affective factors such as mathematics

anxiety or confidence, or how mathematics-related teaching and learning experiences might impact upon beliefs, attitudes or affective factors (Schuck & Grootenboer, 2004). There has also been focus on the mathematics content knowledge of pre-service teachers, as well as their pedagogical content knowledge (Ryan & McCrae, 2006; Southwell, White, & Klein, 2004). What remains as a gap in the research is an attempt to bring together in a cohesive way the components of confidence/affective factors, content knowledge, and pedagogical competence.

The larger study from which this study arose was designed to address in a cohesive, integrated way these components of mathematics teacher professional learning, and in doing so it aimed to tackle the problem of breaking the cycle of tradition. Three components of mathematics education—mathematics content knowledge, mathematics pedagogical competence, and mathematics professional confidence—formed a foundation for a longitudinal action research cycle of curriculum implementation and evaluation in mathematics pre-service teacher education that was first implemented 2002 and is still in progress. The curriculum initiatives and innovations, along with evaluations of their impact upon pre-service primary and early childhood teachers, are documented elsewhere (e.g., Frid & Sparrow, 2003, 2004, 2005). However, although there has been evidence of professional learning by the pre-service teachers that indicates they have the content knowledge, pedagogical competence, and professional confidence to begin to break the cycle of tradition upon graduation, the research thus far has not examined the impact of this professional learning subsequent to graduation. In fact, there is little in the research literature regarding the impact of pre-service mathematics education subsequent to graduation, although feedback on graduates' experiences in the classroom is undoubtedly a valuable component of any evaluation or ongoing implementation of a pre-service program (Schuck, 2006).

Breaking the cycle of tradition will not occur unless graduate teachers are able to put into practice the non-traditional mathematics curriculum and pedagogical beliefs, ideas, and skills they developed in their pre-service programs. Thus, to begin to more comprehensively address the problem of breaking the cycle of tradition, a graduate survey and interview study were conducted to examine the questions:

What do graduates from a pre-service program designed to support teachers to break the cycle of tradition in mathematics education report as their mathematics teaching practices?

What do these graduates report as influences on their teaching practices?

This paper reports on the findings from the exploratory graduate interview study, while the survey findings are reported elsewhere (Frid, Smith, Sparrow, & Trinidad, 2009). The significance of this research, as already indicated, is in its potential to inform mathematics educators of mechanisms and outcomes related to the development of beginning teachers as professionals who have the

capacities to implement innovative non-traditional mathematics teaching and learning practices.

Theoretical Framework

Within the overall action research program, teacher professional development was viewed as a “process of growth in which a teacher gradually acquires confidence, gains new perspectives, increases knowledge, discovers new methods, and takes on new roles” (Jaworski, 1993, pp. 10-11). From this perspective, teacher professional development is a process of ongoing professional learning as a teacher. The curriculum development and implementation of the action research program was built upon two main aspects of the literature related to teacher professional development—adult learning theory and professional empowerment. These are summarised below. Principles for learning and teaching, along with a related curriculum framework (named the *Three C's Mathematics Education Framework*), for the four-year pre-service primary/early childhood mathematics education program were developed using these theories. These are also outlined below, to indicate how the four-year program was designed through analysis and synthesis of relevant research literature.

Adult Learning Theory and Situated Learning

Designing appropriate support for pre-service teachers' learning as mathematics educators requires consideration of how adults learn. Adult learning theory, as proposed by Knowles (1984), emphasises that adults are self-directed learners whose need to learn arises from the interests and challenges of their everyday lives. Further, since adults bring a broad range of experiences, beliefs, values, and ways of functioning to any learning situation, teaching processes that emphasise reflection, self-direction, articulation, scaffolding, and collaboration need to be explicitly recognised and attended to when planning curricula for adults. Learning must be embedded in “contexts that reflect the way knowledge will be useful in real life” (Collins, 1988, p. 2).

The fundamental ideas of adult learning theory are consistent with those of situated cognition or situated learning (Herrington & Oliver, 1995). Herrington and Oliver identified key features of related learning environments: coaching and scaffolding that provide skills, strategies, and cognitive links; reflection to enable meaningful and purposeful learning; collaboration to support personal as well as social construction of knowledge; articulation to consolidate knowledge and foster communication skills; and contextualisation of learning through integration of learning and assessment tasks. These features of adult learning theory and situated learning theories were used in this research in development of the *principles for learning and teaching* for the mathematics education program (see Table 1).

Teacher Professional Empowerment

Mechanisms for growth and change must ask teachers to act as their own change agents, while gently challenging ideas and fostering critical reflection upon ideas and experiences. From an empowerment perspective, teachers should have ownership of their professional learning so that 'coming to know' as a professional is based upon their own reasoning processes in relation to their experiences, and so that their own ideas and voices are effectively integrated with those of others (Cooney, 1996). These ideas are in congruence with adult learning theory, and in particular highlight that professional development is an educative process in which teachers make meaningful and thoughtful choices about their practices rather than having change imposed externally (Robinson, 1989).

In working with pre-service teachers, as in the action research program of this study, an implication of adopting an empowerment perspective for professional learning is that learning activities need to create opportunities for teachers to consider their beliefs and practices, particularly regarding what they value and do, why they do it, and how they do it. Teachers are thereby supported in developing skills for ongoing, lifelong professional learning. In this regard concerning empowerment, Harris, Turbill, Fitzsimmons and McKenzie (2001) noted that:

Only by confronting what you believe and reflecting on what you believe will you become a teacher who can match what you philosophically believe with what you practise in the classroom. Teachers who can do this appear to be the most empowered. (pp. 1-2)

The Three C's Mathematics Education Framework

The literature concerning adult learning theory and teacher empowerment guided development of the *Learning and teaching principles* (Table 1) and the *Three C's Mathematics Education Framework* (Table 2) that formed a foundation for the mathematics education program that was the background context of this research study.

Table 1

Learning and teaching principles for the mathematics education program

Principle	Purpose	Some Learning and Assessment Examples
Scaffolding	Provide pre-service teachers with a professional knowledge base and related skills and thinking strategies in a logical progression of increasing complexity.	rich tasks, model assignments, discussions of and feedback on draft work, examination of children's mathematics work, analyses of mathematics learning activities and resources, portfolio mock interviews.

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Principle	Purpose	Some Learning and Assessment Examples
Reflection	Engage pre-service teachers in development of critical thinking capacities for: self-diagnosis of learning needs; self-directed learning; self-evaluation; and evaluation of educational practices.	'Thinking Heads' reflection sheets, mathematics teaching portfolios, action learning projects, mathematics knowledge self-audit and action plan.
Collaboration	Support broad, multi-foci perspectives and knowledge construction that models the teamwork nature of effective teaching.	'think-pair-share', peer sharing sessions and feedback on draft work, mathematics teaching portfolios, action learning projects.
Articulation	Develop pre-service teachers' capacities to justify, refine, revise, and communicate ideas and related learning.	mathematics teaching portfolios, publishable journal articles, analyses of mathematics learning activities and resources, portfolio interviews.
Contextualisation	Connect learning and assessment with the contexts in which they will be used.	planning of mathematics lessons and programs, self-and peer-assessment, examination of children's work, portfolio interviews, action learning projects.

Table 2
Overview of the Three C's Mathematics Education Framework

Year	Mathematics Content	Pedagogical Competence	Professional Confidence
	(content rich learning activities and exploration of curriculum documents)	(examination of learning theories, teaching resources, technologies, and the mathematics education literature)	(reflection, articulation of ideas, and authentic application of learning)

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Year	Mathematics Content	Pedagogical Competence	Professional Confidence
1st-Year	Focus on the Space strand; overview of other strands; Mathematics Basic Skills Test	Social constructivist perspectives on learning and related practical implications for teaching mathematics	Develop and implement single and short sequences of mathematics lessons for children
3rd-Year	Number & Working Mathematically; number sense and mental computation; numeracy	Examination of children's mathematical thinking and meaning-making	Plan for and assess children's learning (implementation with small numbers of children); Incorporate a wide array of resources and technologies into learning activities
4th-Year	Measurement, Chance & Data, & Working Mathematically	Further examination of a broad range of factors that impact on mathematics learning, including open-ended tasks, inquiry models of learning, games, textbooks, technology, assessment practices, and catering for diversity	Articulate a philosophy of mathematics teaching; develop a mathematics professional teaching portfolio; participate in authentic professional interviews; prepare/implement program for a 10-week school practicum

Method

The research was conducted in two phases: (1) a survey of graduates from 2002-2005 using a written response, short answer questionnaire; and (2) interviews with a sample of respondents from the survey. In addition to gathering demographic data on the graduates' employment history since graduation, the questionnaire was designed to identify key criteria in each of the areas of mathematics, ICT and science, including: regularly used teaching practices; curriculum planning influences; professional development endeavours; formal or informal leadership roles or influences; and views of professional

development needs. The questionnaire design and descriptive findings are reported elsewhere (Frid, Smith, Sparrow, Trinidad, 2009). This paper reports findings of the interview component of the study, which aimed to explore beyond the quantitative and descriptive data of the survey, through the gathering of more elaborated, explanatory data concerning teaching practices. In conjunction with specific examples from reports of teaching or other professional experiences, possible reasons for the nature of reported teaching practices could then be considered, along with possible links between the graduate teachers' current reported practices and previous pre-service learning.

Research Sample

Graduates for this research had completed a four-year pre-service primary or early childhood teacher education degree at a large urban university in Western Australia. The primary degree focuses on Years 1 to 7 children in Western Australian schools (6-12 year olds) and the early childhood degree focuses on Kindergarten to Year 3 children (4-8 year olds). The interview sample consisted of eight graduates selected from over 20 who volunteered out of the 55 who returned a written survey in the mail. This sample was purposeful in that it was chosen to include graduates from all four years of the graduate survey (2002-2005) and graduates teaching in a range of locations (Table 3). It is acknowledged that this sample is not fully representative of the population of approximately 300 graduates from 2002-2005, and that their views and reported practices cannot be generalised to the larger group. However, since the interview component of the study was intended to identify avenues for further research into links between pre-service education and subsequent teaching practices, the diversity of teaching experiences represented by the graduates was considered sufficient for an initial exploration.

Table 3
Teachers interviewed, graduation year, and school employment history

Teacher (pseudonyms)	Graduation year	School employment history
Amanda	2002	metropolitan school
Elaine	2002	rural and remote schools
Lisa	2003	metropolitan school
Nicola	2003	rural school
Nancy	2003	remote school
Alice	2004	rural school, then metropolitan school
Yvonne	2004	rural school
Wendy	2005	metropolitan school

Note: 'remote' was identified according to Department of Education and Training WA school classifications; 'rural' was defined as non-metropolitan but not remote.

Data Collection and Analysis

Interviews were semi-structured in nature, with an initial focus on the following four questions. Interviewees initial responses were then examined further through requests for explanations and specific examples.

1. How did your mathematics education program at university prepare you for the reality of the job?
2. What factors have helped the effectiveness of your mathematics teaching and what factors have limited it?
3. If you were to re-do your mathematics teaching philosophy and portfolio now, what would be different in your beliefs and practices? What elements of your mathematics portfolio have you used to inform your teaching?
4. In what ways do you feel you are or are not making an impact on the children's mathematics learning in your classroom and/or your school?

These questions were designed intentionally to be broad and contextual in nature, rather than asking an interviewee to specifically outline her teaching practices and related influences. In this way the interview data complemented in a holistic way the survey data that had been obtained from specific, directed questions. The contextual nature of each of the four questions provided opportunity for data to be obtained concurrently for both research questions (i.e., for practices and for influences on practices).

The interviews were conducted in the July school term break, by telephone or at the university campus. They were conducted by an independent research assistant who was a qualified teacher, did not know the teachers, and had not been involved in their pre-service education program. Interviews lasted 40 to 60 minutes; they were audio recorded and later transcribed. Data analysis initially involved summarising across all eight teachers the responses for each of the four questions, and then proceeded inductively through a grounded approach (Powney & Watts, 1987). The research assistant and one other researcher worked independently in this process to initially identify key themes related to practices and influences upon practices. These emergent themes and factors were then examined further via re-visiting the transcripts for supporting as well as contrary evidence from the specific examples given by the teachers.

Findings

This section is structured around the two research foci (practices and influences), with the emergent themes each summarised briefly and explicated with examples from the interview data.

Classroom Teaching and Related Professional Practices

Three key aspects of reported classroom teaching practices emerged: (i) non-traditional teaching; (ii) 'fun' mathematics; and (iii) classroom-specific curriculum development. An additional two factors emerged as key aspects of

the teachers' reported broader professional practices related to mathematics: (iv) updating mathematics resources; and (v) acting as a curriculum leader.

Non-traditional teaching. All the teachers spoke of teaching in what could be considered a constructivist perspective because it involved students in developing meanings and understandings through active engagement in learning activities (Clements & Battista, 1990). In this regard they also frequently mentioned using "hands-on" materials as a regular and essential feature of supporting students' mathematical thinking and meaning-making. For example, Elaine stated:

... engaging the children in maths and really getting them to do stuff and working it out in their brains. ... Getting the basic concepts across to them [indigenous students at a small school] was a challenge. So to have hands-on, talking about fractions and things, I'd get a cake and we'd cut it in half, ... and give them the knife and cut it into quarters, and we'd sort of work our way down and they really got to visualise what it was to have a whole and then a half and then a quarter, and that sort of thing because fractions is a really tricky thing to get across to kids who really don't know much about numbers. (Elaine)

Other aspects of constructivist-oriented rather than more traditional teaching were evident in the teachers' references to how they used open-ended tasks, calculators or other technology, while also avoiding prescribed textbook or worksheet exercises. For example:

I do try to think of more open ended activities because I've got such a range of kids. So then I can help the ones that are having problems and give more, and give extra to the ones who can do it all with their hands tied behind their backs. (Wendy)

I did calculators [in my portfolio] and I try to use those with the kids. ... We do lots of fun things and all those sorts of calculator games and stuff like that. (Lisa)

And so I was really determined to use the influence Len Sparrow had on me. ... I didn't use the books in the classroom because they're all those old textbook, workbook things. (Nicola)

Wendy's description of her practices, in particular, reflect a constructivist perspective because she specifically recognises students' differing mathematics understandings and achievement levels, and then plans learning tasks to cater for differences. A focus on "maths understandings" while identifying and catering for students' differing learning levels was also evident in Amanda's comments about her teaching:

I've used my portfolio to inform my teaching. It's very good to get ideas from. ... My assessing of things, because I use Bloom's Taxonomy as stages of assessment to look at my kids, instead of saying they have to have all those bits. I've actually looked at, okay this child's up to here, how can I help them to get to the next level of Bloom's to help to push them along in their maths understandings. (Amanda)

'Fun' mathematics. Most of the teachers mentioned attempting to make mathematics experiences 'fun', so that students would develop positive attitudes towards mathematics and be motivated to do mathematics. What they meant by 'fun' was in fact more extensive in nature than 'enjoyment'—it was learning oriented, involving motivation and enthusiasm, challenge and persistence, success, and a sense that mathematics can be relevant and useful:

Well I know I'm making a difference because they are meeting the criteria of the outcomes. But the thing, the biggest thing I think is that they actually are enjoying it and are asking to do more. They like the challenge of mental maths and things like that, and 'Can we do more?' and 'When are we going to do that?' It's the enthusiasm for learning that's been the main thing, and the fact they enjoy maths is great. (Nancy)

There was also a component of 'fun' mathematics that entailed involving students in experiencing success in their mathematics learning, and that it is "not such a big scary thing at all":

... a lot of the time the kids can be, 'Oh, I can't do maths. I just can't do it.' And therefore they don't try. But if you do it in an interesting context and in a way that encourages them to think about what they're doing it makes them realise that they can do it and it's not such a big scary thing at all. From the children I have taught I can see their change in attitude. ... I remember going through school myself and I wasn't good at maths. ... I think one of my priorities is to make the impression that it's not scary ... they can get through it if they are empowered to get through it. (Elaine)

Classroom-specific curriculum development. The teachers spoke of developing their own mathematics curriculum based on their professional knowledge and judgements. For example, Alice stated:

... select what I'm going to teach the children and the materials I'm going to use, based on research rather than just what I think might do. (Alice)

This development of curriculum locally and flexibly, in the context of their classrooms and their students' learning needs was a prominent aspect of the teachers' comments about their values and teaching practices. Some had taught in schools in which "you had to follow the textbook" (Elaine), yet even then they made efforts to "be creative" by incorporating hands-on activities and having students use their "brains a bit". In this regard they expressed strong beliefs that a mathematics curriculum cannot be based largely on prescribed textbook or worksheet activities if it is to support effective mathematics learning for the diversity of students in a classroom. Inherent in these beliefs are non-traditional views of mathematics learning and teaching; specifically, that the same exercises at the same time are not appropriate for catering for students' developmental and achievement levels. Many of the teachers expressed a strong dislike of textbooks and worksheets for mathematics teaching, preferring instead to use their professional knowledge and knowledge of their students to make mathematics curriculum decisions:

We did try to program together for the first term and it just didn't work. It felt like I was banging my head against a brick wall, because her kids do worksheets, lots and lots of worksheets, and they're just five [years old]. (Wendy)

You can pick and choose the parts that suit you and the different, ... like using the hands-on stuff, like using calculators. ... We make our own lessons up because we said you can't have a textbook in Years 1 and 2. It's a guideline. ... there's still room for extending the kids ... if they can do what's in the book you can still go over and above it if you feel they need to, or go back and re-teach a few things if they've missed something. (Lisa)

Updating mathematics resources. The teachers made frequent mention of either making their own resources or playing a key role at the school in ordering new mathematics resources. Examples of their statements concerning mathematics resources included:

We don't have that many resources. ... I've had to go and actually search for things to actually bring into my classroom to be able to do maths and science. (Wendy)

I'm the person who coordinates the literacy and numeracy budget, so I've bought lots of stuff. Not just for my classroom, it can be used in other classrooms, but because of my teaching style I tend use them the most. I'm trying to encourage others to work more with other types of things [other than worksheets]. (Nancy)

The comments of Wendy and Nancy indicate they did not see their schools' resources as sufficient for mathematics teaching. In fact, the nature or availability of mathematics resources were a factor that impacted upon teaching activities, with many of the teachers stating a lack of resources restricted what they did in their mathematics teaching:

Factors limiting maths teaching is mainly lack of resources, but also that can be a help because it forces you to be more creative and find different ways, making resources or doing something a bit differently so you don't need the expense of resources. (Alice)

Acting as a mathematics curriculum leader. There was evidence that some of the teachers, even though they were 'novice' teachers, were taking on mathematics leadership roles in their schools. In some cases these roles arose from personal initiatives to do new things in a school related to mathematics learning. For example, Nicola enhanced the school newsletter with a "maths corner where I put a maths strategy in for the parents to help their kids. And a maths competition". Other forms of leadership involved encouraging and supporting other teachers to try new things, by sharing ideas, expertise or resources:

They gave me the opportunity to do the role [maths specialist], which I thought was quite strange because I was very frightened of maths. I thought, 'Why me?' ... So I go in and I actually give teachers ideas on how they can use the

technology with their maths. We've got all these interactive whiteboards, so I train teachers on using the interactive whiteboards in their maths. (Amanda)

Every time I come back from a conference I report at the following teachers' meeting on what I've learned and show them some stuff. ... Last year one of the teachers was particularly receptive to the calculator program I brought back for him ... so I had a win there. (Nancy)

Yet another form of leadership that was mentioned was that of acting as a role model, simply by daring to do different things that later proved to be effective in supporting students' mathematics learning. Nicola outlined in detail a specific example in this regard:

That's actually been really amazing, the difference. ... They have done so much better ... from someone who doesn't use the [text]books. ... The other Year 6/7 teachers, when it's maths they opened up to a certain page in the book and they all did that in the book. Now I never did that, and I was worried about whether they [the students] would be okay with everything. But from the results from different maths tests that they have to do for Year 8, it's really shown me I've improved their maths. ... I've had some teachers who have said to me, 'I've never thought of doing it that way.' (Nicola)

These examples of curriculum leadership indicate a degree of confidence and professional knowledge on behalf of the teachers. They indicate these novice teachers had mathematics pedagogical knowledge and skills that they believed in and knew how to implement in practical ways in classrooms. Their professional confidence to put these beliefs and related knowledge into practice, even in situations where they were not directly supported by colleagues, appeared to be related to their convictions regarding effective mathematics teaching. More will be said on the possible links here between professional convictions, competence, and confidence in the final discussion section of this paper.

Influences on Practices

Three factors emerged as key influences upon reported mathematics teaching practices: (i) university learning; (ii) the diversity of learners in classrooms; and (iii) school support or restrictions.

University learning. Since the graduates' mathematics teaching portfolios were part of their university learning and were specifically asked about in the interviews, the emergence of 'university learning' as an influence upon teaching practices was at least partially a product of the data collection instrument. However, of relevance here are what aspects of university learning other than mathematics teaching portfolios emerged as relevant, and which aspects of mathematics teaching portfolios had a continuing influence.

With regard to portfolios, specific teaching ideas such as the use of calculators, other technology, games, or mental computation were cited as useful in subsequent teaching. To a lesser extent there was mention of underlying

principles for teaching particular mathematics concepts. Examples of these aspects of portfolios include:

I did calculators [in the mathematics portfolio] and I try to use those with the kids. ... We do lots of fun things and all those sorts of calculator games and stuff like that. (Lisa)

I've definitely used my maths portfolio, because I looked at maths through technology. So the whole thing was based on how technology can be integrated into our maths. (Amanda)

I found it very comprehensive and still applicable [mathematics portfolio]. All the principles are there. ... I've gone back and looked at stuff and asked, 'What does that really mean?' and 'Why am I doing this again?' just to clarify the basis from where I'm coming. Or what's the process of counting? And what should I be looking for? Or all those articles we had. I've got them in a file, project files, and I go back to them. (Wendy)

What received the most mention concerning the graduates' mathematics teaching portfolios was a mathematics teaching philosophy developed as part of their portfolios. Some of the graduates' comments indicated that their philosophies were a key influence on their professional thinking as a mathematics teacher:

I have used my general mathematics philosophy which sort of guides my maths teaching in that I still have the same values I did when I did the portfolio, and I still want to achieve the same things with my children. (Alice)

The main thing is my philosophy, my beliefs. ... I don't think I'll ever stop believing kids need to have fun in their maths, and they need to think and do and play around with stuff, and talk about it. Those are my core beliefs and I don't think they'll change. They might adapt slightly. (Lisa)

Beyond the learning attained at university from development of a mathematics teaching portfolio, what emerged as highly influential were the mathematics education lecturers and how they served as role models:

My first year out I had Year 6/7's and I was determined that if I didn't use the stuff I'd learnt from uni in my first year I never would. And so I was really determined to use the influence Len Sparrow had on me. (Nicola)

I still think back and think, 'What did I do in maths class? How can I teach this concept to my kids?' And I was chatting to some other graduates at the Beginning Teachers' Seminar and they were saying that they too have Len and Sandra moments. 'Oh, what did Len do, what did Sandra do for that to help?' (Wendy)

Diversity of learners in a classroom. The graduates spoke of the challenges of teaching mathematics to students of a wide range of knowledge and skills within one classroom. They made it clear they were aware of this diversity in achievement levels. For example:

I think mainly what's limited it is having such a wide range of difference, ability wise. Just having some kids that had no idea how to add numbers unless they've got counters, and then having other kids that can do huge multiplications in their heads. ... At the moment we program together and talk about where the kids need to go, and because there are sometimes two teachers in the classroom [classes are combined to group by achievement level for maths] you can pick up on, you can monitor different students and where they are at and where they need to improve. (Yvonne)

What has helped would probably be the diversity of the children in the classroom, because that makes me look really hard at what I'm teaching and how I can include all the children, and so they can all learn something from a particular activity. (Alice)

What is noteworthy here concerning these two excerpts from the interviews is that 'diversity' emerges as both a helpful and a limiting influence upon teaching practices. From either viewpoint, however, the diversity of learners was impacting upon curriculum planning because the teachers were endeavouring to cater for it to ensure all students were being supported to progress in their mathematics learning.

School support or restrictions. A key feature of this factor was that personal beliefs and values related to mathematics teaching and learning could lead to frustration:

The standard at that school was that you had a textbook and you had to follow the textbook, so I really didn't have a whole lot of room to be creative with those kids. ... I felt restricted because at uni everything was so exciting and energetic and so hands-on. (Elaine)

However, at the same time, some of the teachers noted specifically how their convictions to follow their beliefs, regardless of restrictions or the practices of other teachers in the school, were a guiding source for daring to be different and enacting non-traditional teaching practices. For example:

Things that have limited it? Simply old ways of thinking. You know you get really good teachers you can collaborate with, that have other experience, but you get other teachers that say, 'No calculators in this classroom', or ... 'My kids aren't using counters for things like that'. It's my classroom and if I want them to use counters, well they're going to use counters basically. And that's what my maths beliefs are and it's going to work. And you know what? Sometimes you have to say, 'Stuff it'. ... You just have to take a bit of a risk sometimes. (Lisa)

Conclusions

In summary, for the first research question of this study (graduates' reported teaching practices), three key aspects of classroom mathematics teaching practices emerged, along with two additional aspects of broader professional practices related to mathematics teaching: (i) non-traditional teaching; (ii) 'fun' mathematics; (iii) classroom-specific curriculum development; (iv) updating

mathematics resources; and (v) acting as a curriculum leader. For research question two (influences upon teaching practices), three factors emerged: (i) university learning; (ii) the diversity of learners in classrooms; and (iii) school support or restrictions.

The findings indicate that it is possible to 'break the cycle of tradition' in primary mathematics education. More specifically, it is possible to prepare pre-service primary/early childhood teachers who, subsequent to graduation, have the content knowledge, pedagogical competence, and professional confidence to plan for non-traditional mathematics curricula. They can develop classroom-specific mathematics curricula that cater for diverse learning needs, use constructivist-oriented teaching strategies, and foster a view of mathematics as a challenging, relevant, enjoyable, and achievable endeavour. Further, they can act as change agents through a variety of forms of curriculum leadership, including serving as a specialist or coordinator, being a role model, fostering collaboration and sharing of ideas, or initiating new ideas and activities at a school.

However, the small-scale nature of this study necessitates that these conclusions be made with some qualifications, because the findings cannot be generalised to all graduates. They cannot in fact be claimed for all eight of the teacher interviewees. For seven of the eight teachers the evidence was convincing with regard to the conclusions. The eighth teacher, Yvonne (2004 graduate), was somewhat different to the others in that she spoke of struggling with her mathematics teaching and not knowing what to do with the diversity of achievement levels in her classroom, and she could say very little about what she had learned from her pre-service program or her mathematics teaching portfolio.

The findings do, none the less, show what is possible and what is promising. It is in this context that the following discussion of practical implications examines aspects of the teachers' pre-service experiences and reported current practices that appear to be prominent in their capacities to begin to break the cycle of tradition: (i) development of a mathematics teaching philosophy; (ii) breadth and depth in mathematics pedagogical knowledge; and (iii) professional confidence.

Development of a Mathematics Teaching Philosophy

The fact that most of the teachers, even up to four years later, could outline how their mathematics teaching philosophy impacted upon their practices implies the development of a philosophy as a requirement of their pre-service program supported their later teaching endeavours. They spoke of their beliefs and values, but more importantly, of how these guided their practices. This latter point must be noted explicitly in that the development of a mathematics teaching philosophy, in conjunction with a mathematics teaching portfolio, entails more than outlining beliefs about mathematics teaching. It necessitates translating beliefs into practice; that is, articulating how classroom environments, learning and assessment activities, and teaching strategies can be constructed to attain the goals of one's beliefs. A philosophy is more complex than an outline of beliefs,

and thus, this research goes beyond prior research related to the nature and role of beliefs in mathematics teaching. Much previous research has neglected the practical components of an examination of beliefs, by not addressing *how* to put beliefs into practice in practical ways in the context of actual classroom teaching (e.g., Grootenboer, 2006; Wilson & Thornton, 2006). A mathematics teaching philosophy and related teaching portfolio require this articulation and application. Hence, a practical implication of this research study is that the development of a mathematics philosophy along with a mathematics teaching portfolio can support professional learning outcomes that can actually be put into practice to begin to break the cycle of tradition.

Breadth and Depth in Pedagogical Knowledge

The teachers showed breadth in their pedagogical knowledge in that they displayed awareness of a wide range of mathematics resources, teaching strategies, and learning activities that can motivate and support meaningful mathematics learning. They showed depth in their pedagogical knowledge in that they could articulate *why* they used particular methods in relation to *how* they facilitate mathematics learning. That is, the teachers displayed understandings of the research on how children learn mathematics, and importantly, how to apply those learning theories to the development of mathematics curricula. The implications here are that teachers who have understandings of mathematics pedagogy, *along with* capacities to translate those understandings into classroom learning experiences, will begin to be able to break the cycle of tradition. What is not as clear here, in comparison to the role of the teachers' philosophies, is the degree to which the teachers' pre-service program had direct impact upon their later breadth and depth in pedagogical knowledge. It is however reasonable to note that a key aspect of the pre-service teachers' development of a mathematics teaching portfolio was that they had to justify the content of their portfolios. Specifically, they had to use a framework of 'what-why-how' (Frid & Sparrow, 2003, 2004) to prepare portfolio items and related classroom mathematics learning and assessment activities, and to then justify them within authentic interviews with school principals and other educators.

Professional Confidence

Several of the teachers were acting in leadership roles, and some clearly were daring to "take a bit of a risk" to be different, even in the face of restrictions or adversity. It takes professional confidence to take the risks needed to enact teaching practices that differ to those of colleagues in a school. The fact that these actions were being taken by 'novice' teachers needs further examination. These novice teachers exhibited a degree of professional empowerment through the sense of ownership they displayed of their beliefs and related professional knowledge, and their capacities to articulate what they value and do, why they do it, and how they do it (Cooney, 1996; Harris et al., 2001; Robinson, 1989) In

this study there was evidence that the teachers' professional confidence arose from awareness of their beliefs, values, and philosophy, along with convictions to act in congruence with them. The additional factor in evidence was that they had well-developed pedagogical knowledge of how to translate their beliefs and philosophy into practice. Their professional confidence was not independent of their teaching philosophy and pedagogical competence; they were not separate. Thus, a practical implication here is that pedagogical competence along with related professional confidence can lead to teachers who can begin to break the cycle of tradition.

In conclusion, a final statement of what is promising in addressing the problem of breaking the cycle of tradition is that this study implies that it is possible to prepare pre-service teachers to be thinking-acting-leading mathematics teachers—teachers who think critically about their professional practices while also serving as educational leaders who take action and implement changes to enhance mathematics teaching and learning.

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